THE INFLUENCE OF TEXTURE AND COMPOSITION OF SURFACE ON THE ATTACHMENT OF SEDENTARY MARINE ORGANISMS *

C. M. POMERAT AND C. M. WEISS

Medical Branch, University of Texas and the Woods Hole Oceanographic Institution *

Marine installations of various kinds necessitate exposure of construction materials under sea water. Data dealing with the amount of fouling accumulated by such materials are not abundant. Information which might be of aid to the scientist seeking the most favorable material upon which to collect sedentary organisms for study is also scanty. The present study was undertaken to determine the effect

TABLE I

Effect of surface texture of glass on attachment of sedentary organisms. (Numbers of individuals on each surface of 80 square inches of plate)

Surface number	Plain 0	Sand-blasted 1	Factrolite 2	Prestlite 3	Ribbed 4	Pentecor 5
Series No. 1, Tahiti Beach[1] 39 days (8/22/42–9/30/42)						
Hydroides sp.	143	265	152	506	349	197
Spirorbis sp.	85	188	122	90	163	110
Barnacles	1,948	1,072	1,162	975	1,674	2,140
Total	2,176	1,525	1,436	1,571	2,186	2,447
Average pop.	725.3	508.3	478.7	523.7	728.7	815.7
Average/square inch	9.1	6.4	6.0	6.5	9.1	10.2
Series No. 2, Miami Beach[2] 17 days (8/22/42–9/8/42)						
Wet weight (grams)	51.0	45.5	50.0	41.0	50.0	41.0
Dry weight (grams)	8.5	6.4	7.9	5.5	7.5	8.8
Barnacles	308	227	268	213	263	331
Series No. 3, Miami Beach[2] 30 days (9/15/42–10/15/42)						
Wet weight (grams)	164.5	174.0	149.0	150.0	126.0	155.5
Dry weight (grams)	51.5	50.0	30.0	24.0	24.0	33.0
Barnacles	642	515	554	778	798	977

[1] Subtropical testing service. [2] Beach boat slips.

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of surface irregularities and of substrate composition on the establishment of sessile populations. The experiments were conducted in Biscayne Bay at Miami, Florida, where subtropical conditions favor the attachment of fouling organisms throughout the year.

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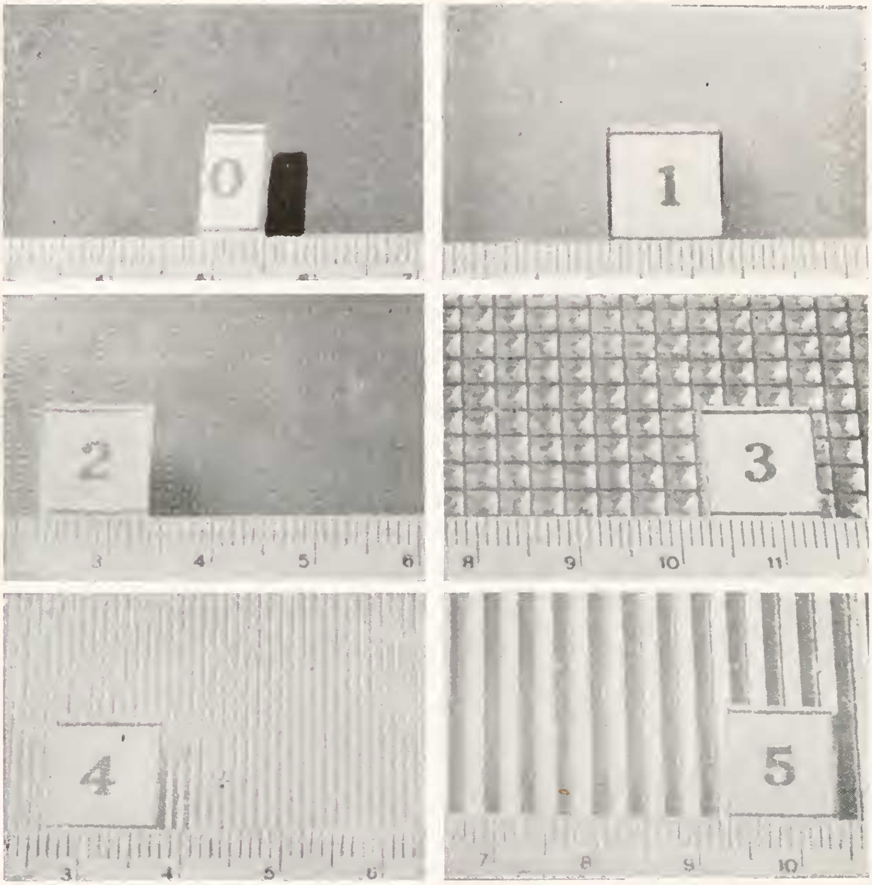

FIGURE 1. Glass surfaces used in testing the relation of surface irregularities to fouling. 0. Plain. 1. Sandblasted. 2. Factrolite. 3. Prestlite. 4. Ribbed. 5. Pentecor.

EFFECT OF SURFACE IRREGULARITY

Commercial glasses, manufactured by the Pittsburgh Glass Company, with various surface irregularities were used for this study. Six 8 × 10 inch glass plates were assembled, irregular surface down, in a rack suitable for floating on the surface of the water. The floats were constructed in such a way that sea water could move freely on both sides of the exposed surface. The backs of the panels which were all relatively smooth were placed upward. The fouling on the back surfaces was not recorded. The surface irregularities of the panels are shown in Figure 1 and may be described as follows:

Surface Number:

0.	*Plain*	Smooth glass, polished.
1.	*Sandblasted*	Glass sandblasted on lower side.
2.	*Factrolite*	Surface consisted of pyramidal depressions of which there were about 144 per square centimeter.
3.	*Prestlite*	Approximately nine pyramidal depressions per square centimeter.
4.	*Ribbed*	Surface of V-shaped grooves, nine grooves per centimeter of width.
5.	*Pentecor*	Approximately three V-shaped grooves per centimeter of width.

Results obtained from three series of experiments in which the glass surfaces were exposed are shown in Table I.

The Sessile populations which grew on the glass plates were composed primarily of barnacles and tubeworms, with irregular, perhaps seasonal, appearances of tunicates and *Anomia* sp. Barnacles (*B. improvisus* and *B. amphitrite niveus* in order of relative abundance) were numerous in both locations, but those at Tahiti Beach were always very small compared to those at Miami Beach. Many more barnacles attached to the lower (shaded) surfaces of the panels than to the upper surfaces where light was more abundant. This is in agreement with the experience of Pomerat and Reiner (1942), who report that larger numbers of barnacles accumulate on dark surfaces than on light surfaces. The shaded undersides of the glass panels, being darker than the upper sides, appear to attract more cyprids and hence show a greater barnacle accumulation.

The various surface textures of glass had little influence on the number of attached organisms. In these experiments barnacles were consistently slightly more numerous on Pentecor than on smooth glass. This behavior was confirmed in the experiment reported in the following section although conditions of exposure were not exactly parallel. In the first experiment the glass panels were floated at the surface in a shaded location, while in the second they hung vertically below low tide

TABLE II

Influence of substrate on fouling, sixty days' exposure at the beach boat slips, September 25, 1942–November 25, 1942

Substrate	Weight of fouling on panel area of 264 sq. in., that of wood panels employed — Wet weight grams	Dry wt. grams
1. Dade County pine	675.1	346.5
2. Gum	1127.6	531.4
3. Magnolia	1165.4	446.4
4. White pine	968.7	446.8
5. Cypress	954.8	392.0
6. Tile	980.1*	487.3
7. Cement	1033.0*	534.1
8. Glass	386.1	167.3

* Corrected to an area, 264 sq. in., equal to that of the wood panels.

under sun exposure. Counts of tubeworms were made on only one set of exposures. *Hydroides* sp. was most abundant on Prestlite and *Spirorbis* sp. was most abundant on sandblasted glass.

Composition of the Surface

Unpainted panels of wood of five species, clay roofing tiles, cement roofing plates, and a glass panel were exposed for 60 days at the Beach Boat Slips in Miami Beach.

Table III

Effect of substrate on fouling, exposures of three months at South Dock, Belle Isle, Miami Beach, Florida, January 9, 1943–April 9, 1943, all materials applied to, or mounted on, wood unless otherwise noted

Composition of surfaces	Wet weight* (grams)	Dry weight* (grams)	Number* of barnacles	Notes
Plastics				
1. Celluloid	3.8	2.2	11	Thin coat of algae.
2. Plasticel	24.3	12.2	124	Barnacles' bases easily removed.
3. Lucite	5.6	1.7	41	
4. Formica	6.9	3.2	11	
5. Isobutyl Methacrylate	15.4	7.2	70	Film applied to glass panel. Plastic peels intact with barnacles.
Glass				
6. Prestlite	57.0	25.2	176	Some barnacles 12 mm. across.
7. Pentecor	46.0	25.0	148	Some barnacles 12 mm. across.
8. Sandblasted	23.6	7.0	46	6 calcareous tubeworms; tunicates.
9. Smooth	4.5	1.7	16	Green slime may have caused fish to remove young barnacles.
*Paints and ingredients***				
Coatings applied to steel panels				
10. Ester gum vehicle	36.3	8.1	58	Tunicates and bryozoa.
11. Rosin vehicle	2.7	0.4	0	Fish spawn both sides.
12. Anticorrosive paint 42-A	2.7	0.5	9	Baracles very small.
13. Vehicle of 15RC	6.1	3.3	43	
14. Antifouling paint 7C	0.0	0.0	0	Some slime film.
15. Antifouling paint 8C	0.6	0.3	14	Small barnacles close to edge.
Coatings Applied to Wood				
16. Ceraloid	57.6	38.5	183	
17. Paraffin	11.3	6.1	59	Lomnoria active in breaking paraffin.
18. Asphaltum	121.4	34.3	768	Barnacles only.
19. Asphaltum varnish	67.8	13.8	256	Some bryozoa.
20. Spar varnish	45.1	7.0	304	
21. Navy grey	41.6	5.6	150	Algae.
22. Anti-corrosive 42-A	48.2	10.7	156	

* Corrected to an area of 144 square inches.

** Anticorrosive 42A is a standard Navy formula. Vehicle of 15RC is the non-pigmented portion of a standard Navy antifouling paint. Antifouling paints 7C and 8C are experimental modifications of a standard Navy antifouling paint of the cold plastic type in which the toxic pigment is reduced to 50 and 60 percent of the normal value.

TABLE III—*Continued*

Composition of surfaces	Wet weight* (grams)	Dry weight* (grams)	Number* of barnacles	Notes
Woods				
23. Dade County pine (soaked 60 days)	395.2	120.7	748	Bryozoa.
24. Gum (soaked 60 days)	452.1	133.4	686	
25. Dade County pine (unsoaked)	144.3	27.3	125	Hydrozoa, bryozoa.
26. Gum (unsoaked)	249.8	43.5	222	
27. Soft pine	57.6	11.5	184	
28. Teak	143.8	88.7	306	Large barnacles.
29. Maderia	173.7	84.2	358	Many fish eggs.
30. Greenheart	77.0	40.8	342	
31. Balsa	2.9	1.6	5	Wood very soft.
Metals				
32. Steel	224.4	42.8	88	
33. Galvanized iron	2.6	0.7	6	Barnacles easily removed.
34. Zinc	1.0	0.2	0	Active corrosion.
35. Lead	30.6	50.9	396	Large barnacles.
36. Monel	1.6	0.5	6	Many fish eggs.
37. Nickel	43.2	10.7	126	
38. Galvanized iron pipe	4.7	3.0	27	Barnacle on rusted threads and damaged edges.
Miscellaneous				
39. Linoleum	79.7	23.0	193	
40. Deck canvas no. 10	5.1	2.3	7	Sagging-algae eaten by fish.
41. Sole leather	32.4	12.4	66	
42. Masonite, heat tempered	138.6	31.8	594	Brown tunicates.
43. Asbestos	284.2	65.9	980	Bryozoa, *Anomia*, hydrozoa, calcareous tubeworm.

All panels were suspended in a vertical position approximately two feet beneath the mean low water mark. The site was well shaded by a protecting roof. The results obtained are presented in Table II.

The weights of the populations (barnacles, tubeworms, tunicates, bryozoa, and algae) which accumulated on the woods, tile, and cement were of the same order of magnitude, though variations as great as 59 per cent were observed. The weight of organisms accumulated on glass was approximately 30 per cent of that collected from other substrate materials.

A much larger number of materials were tested in a second experiment, the results of which are given in Table III. Exposure was made for three months at South Dock, Belle Isle, in Miami Beach, where conditions of bright sunlight, active current movement, and moderate fouling incidence were found. Growth on the panels consisted primarily of barnacles (*B. improvisus* and *B. amphitrite niveus*) with occasional tufts of hydrozoa and patches of colonial tunicates. A blanket of algae having very short filaments grew on panels of light color or shaded background. Large sets of fish eggs were found on the rosin vehicle and Monel. Borings of *Limnoria* sp. were everywhere evident in unprotected wood.

The substrates accumulating heaviest populations were asbestos, asphaltum, Dade County pine (pre-soaked 60 days), gum wood (pre-soaked 60 days) and Masonite. Asbestos shingle, commonly used as clapboarding, yielded the richest harvest as measured by the number of barnacles. A comparison of asbestos and Masonite, two of the best collectors, is shown in Figure 2. The asphaltum used was of the type employed as aquarium cement. It accumulated barnacles only.

Panels of gum and Dade County pine, which had been exposed for 60 days in the earlier test reported in Table II, were included for comparison with unsoaked specimens of these woods. The unsoaked woods developed much less fouling.

FIGURE 2. Accumulation of fouling organisms on masonite and asbestos after 90 days' exposure at Belle Isle, Miami Beach, Florida.

Intact galvanizing on iron was very resistant to marine life. No barnacles were obtained on zinc, on the experimental antifouling paint 7C or on rosin vehicle, a common paint component.

Materials with hard non-porous and non-fibrous surfaces were in general rather poor collectors of fouling. The best accumulation of sedentary populations was found on surfaces which were porous and/or fibrous. Surface of paints, paint ingredients and linoleum are in general non-porous and non-fibrous. Compared to the size and strength of the barnacle cyprid they are also smooth and hard. The histogram (Fig. 3) summarizes the collective efficiency of the substrates.

Some results were undoubtedly spurious, and these should be noted. Fouling on the antifouling paint 8C which occurred along the edges of the panel was probably

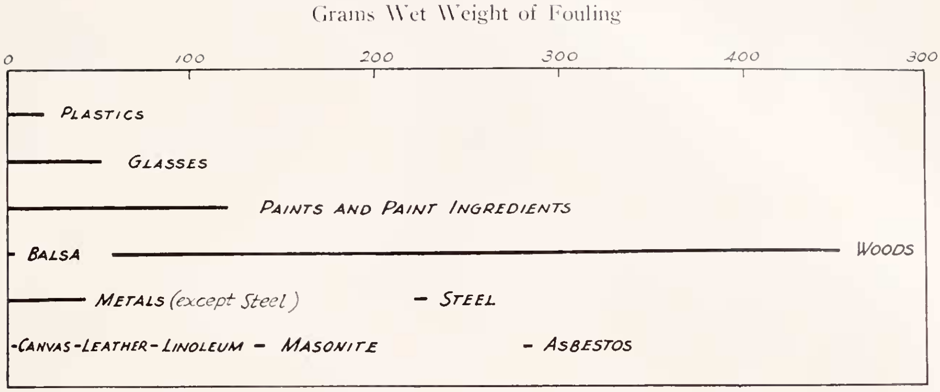

FIGURE 3. Relative amounts of fouling on various classes of materials used as test panels.

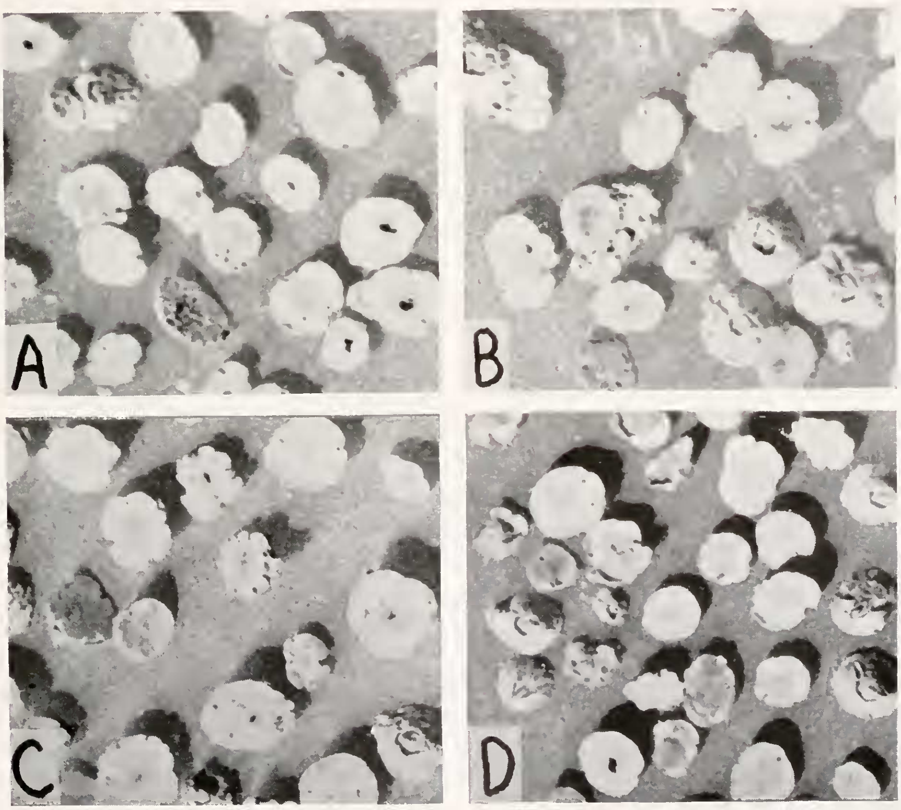

FIGURE 4. Bases of barnacles grown on various substrates. A. Navy grey. B. Antifouling paint 15RC. C. Ester gum. D. Anticorrosive paint 42A.

due to imperfections of the paint surface. In contrast, 7C which contained less copper was not fouled. Deck canvas and smooth glass both supported a culture of green algae which evidently served as food for fish. Active feeding on these panels unquestionably disturbed other fouling organisms. Balsa wood was apparently sloughing its surface and thus loosening attached forms. In spite of these minor qualifications, the results involve a range of population numbers sufficiently wide to indicate the relative merits of the substrates used.

One of the most interesting of the results was observed when barnacles were removed from the various substrates. Some of the substrates bore barnacles with deeply scalloped margins (Fig. 4) instead of the typical smooth edges. These margins suggested that localized irregular marginal growth interruptions had taken place. Such barnacles were collected from:

Spar varnish
Linoleum
Navy grey topside paint (P–50)
Antifouling paint vehicle 15RC
Ester gum paint vehicle
Anticorrosive paint 42–A

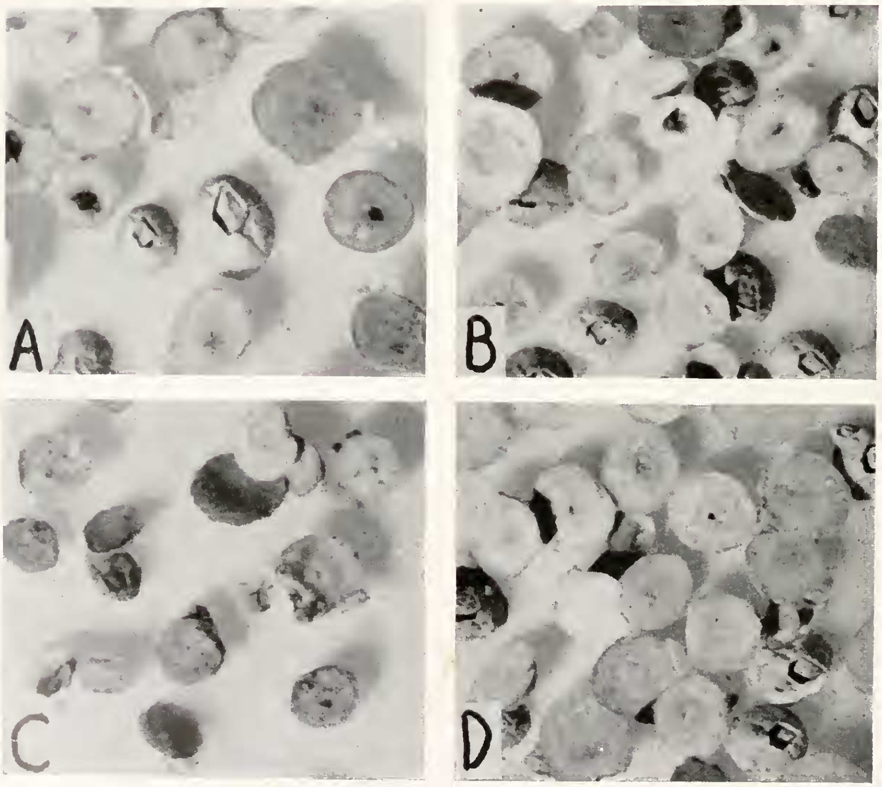

FIGURE 5. Bases of barnacles grown on various substrates. A. Isobutyl methacrylate. B. Plasticel. C. Soft paraffin. D. Ceraloid.

Barnacles growing on soft paraffin had distinctly concave bases. Mosaics of bases with angular margins were typical of barnacles attached to lead but were also found on other overcrowded substrates. It was possible to remove barnacles with intact bases very easily from several materials, including plasticel, ceraloid, and isobutyl methacrylate (Fig. 5). This finding might prove useful in designing experiments in which the minute anatomy of basal structures was to be studied.

Summary

1. Submerged samples of 40 different construction materials were used as substrates for the collection of sedentary populations. The barnacle counts in the populations ranged from 980 on asbestos shingles to zero on zinc and on two paint coatings, after three months' immersion in Biscayne Bay at Miami Beach, Florida.

2. Various surface textures of glass plates were found to exert no significant influence on the accumulation and growth of sedentary marine organisms, although smooth clear glass accumulated smaller populations in the comparatively short exposure periods, 1–3 months .

3. The results suggest that efficiency of a substrate as a fouling collector is in general correlated with porosity of surface or with fibrous nature of surface. Smooth, non-porous, non-fibrous surfaces, especially if also hard, seem to be poor accumulators of sedentary organisms.

4. Further testing of substrates is greatly to be desired in this connection.

REFERENCES

Pomerat, C. M., and E. R. Reiner, 1942. The influence of surface angle and of light on the attachment of barnacles and other sedentary organisms. *Biol Bull.*, **82** (1) : 14.